The Energy Cost of Steady State Physical Activity in Acute Stroke

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Objective: Cardiorespiratory fitness levels are very low after stroke, indicating that the majority of stroke survivors are unable to independently perform daily activities. Physical fitness training improves exercise capacity poststroke; however, the optimal timing and intensity of training is unclear. Understanding the energy cost of steady-state activity is necessary to guide training prescription early poststroke. We aimed to determine if acute stroke survivors can reach steady state (oxygen-uptake variability ≤2.0 mL O_2/kg/min) during physical activity and if the energy cost of steady state activity differs from healthy controls. *Material and Methods:* We recruited 23 stroke survivors less than 2 weeks poststroke. Thirteen were able to walk independently and performed a 6-minute walk (median age 78 years, interquartile range [IQR] 70-85), and 7 who were unable to walk independently performed 6 minutes of continuous sit-to-stands (median age 78 years, IQR 74-79) and we recruited 10 healthy controls (median age 73 years, IQR 70-77) who performed both 6 minutes of walking and sit-to-stands. Our primary outcome was energy cost (oxygen-uptake) during steady state activity (i.e., walking and continuous) sit-to-stands, measured by a mobile metabolic cart. *Results:* All stroke survivors were able to reach steady state. Energy costs of walking was higher in stroke than in controls (mean difference .10 mL O_2/kg/m, P = .02); the difference in energy costs during sit-to-stands was not significant (mean difference .11 mL O_2/kg/sts, P = .45). *Conclusions:* Acute stroke survivors can reach a steady state during activity, indicating they are able to perform cardiorespiratory exercise. Acute stroke survivors require more energy per meter walked than controls. **Key Words:** Stroke—acute—oxygen consumption—exercise—energy cost—physical activity—indirect calorimetry.

Introduction

Cardiorespiratory fitness levels are very low in stroke survivors, with peak volume of oxygen uptake (VO_{2peak}) levels ranging from 29% to 87% of VO_{2peak} levels of healthy controls.[1] These low fitness levels put stroke survivors at risk of losing their ability to independently perform activities of daily living.[2] Fitness training after stroke can lead to improvements in VO_{2peak} levels, walking ability, and balance.[3] Fitness training is a recommended component of stroke rehabilitation[3-5] and should be initiated as soon as the patient is hemodynamically and neurologically stable.[4,5] However, the evidence for the effectiveness of fitness training is mostly based on research conducted in stroke survivors beyond 3 months poststroke.[3] Currently, there is little evidence and no consensus on how early and at what intensity fitness training should commence poststroke.[3,4]

Stroke survivors experience a wide range of impairments that reduce their tolerability to exercise and could make everyday activity more effortful, that is, require more energy.[6,7] Cardiorespiratory fitness training performed below

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the anaerobic threshold might be appropriate for acute stroke survivors with limited exercise capacity. Such exercise can be sustained for a duration necessary to generate benefits, and at an intensity that avoids the muscles going into oxygen debt, that is, steady state exercise.[8] During steady state activity, the oxygen supply meets the oxygen demands of muscle tissue, which allows sustained physical activity. In contrast, non–steady state activity requires level of energy that can only be supplied over a short period of time before muscles go into oxygen debt.

The higher energy demands poststroke can lead to fatigue and can impact the ability to perform activities.[9] Higher energy demands are therefore likely to also impact the ability to perform steady state exercise and to sustain continuous exercise, which is needed to improve fitness. We showed that energy cost of walking is higher for stroke survivors less than 1 month poststroke than healthy controls, but there is no evidence for the energy demands of stroke survivors early after poststroke (i.e., <1 month).[10] Whereas the energy cost of *walking* has been extensively investigated in stroke,[10-12] the energy cost of activities *other than walking* has not. This is problematic, given a large proportion of stroke survivors are unable to walk. According to a large cohort study (n = 804) in which recovery of walking ability after stroke was assessed in the first week after stroke onset, more than half of stroke survivors have difficulty walking in the first week after stroke.[13] The variability in cardiorespiratory fitness levels and impairments early after stroke dictates an individualized approach to exercise prescription.[4] By choosing activities and exercises based on the individuals' capacity, both ambulatory and nonambulatory stroke survivors will be able to engage in fitness training.

Our main aims were (1) to determine if acute stroke survivors could reach a steady state condition during 6 minutes of moderate activity, and (2) to determine the difference in *energy cost* of steady state activity between acute stroke survivors and healthy controls. Energy cost is taking the speed of movement into account, which can differ substantially between stroke survivors and healthy controls.[10] We defined energy cost as oxygen-uptake per unit of activity; for example, energy cost of walking is expressed as mL O_2/kg/m. Additionally we determined the difference in *energy expenditure* between acute stroke survivors and controls. Energy expenditure is defined as O_2 uptake over time and expressed as mL O_2/kg/min. Lastly, we explored if energy cost of activity in stroke survivors is related to fatigue and perceived exertion of activity.

Material and Methods

Participants

Stroke survivors who met the following criteria were eligible to participate: (1) over 18 years of age, (2) admitted to a hospital, (3) within 2 weeks of confirmed stroke, (4) cognitively able to give written consent, (5) sufficient English language to complete questionnaires and follow instructions, and (6) medically stable as assessed by their treating physician.

Exclusion criteria were (1) comorbidities that impaired the ability to perform 6 minutes of activity (e.g., lung emphysema, chronic obstructive pulmonary disease, lower limb surgery) and (2) other neurological conditions (e.g., Parkinson's disease, multiple sclerosis). The same exclusion criteria applied to controls, with the additional criterion of not having a history of stroke. We recruited controls by distributing flyers in the local area. Participants were recruited from November 2013 to November 2015 and all provided written informed consent. The study was approved by the Austin Health Human Research Ethics Committee (reference number: H2011/04447).

We based sample size calculation on the findings of 2 studies in which the energy cost of walking in subacute stroke survivors was assessed; the estimated precision-based sample size needed was 10 stroke survivors and 10 controls to find a difference of .64 mL O_2/kg/m (95% confidence interval [CI] of .44-.85).[11,12] Given the likelihood of a high degree of variability in the performance of 6 minutes of physical activity in the first 2 weeks after stroke, and the fact that we aimed to include stroke survivors across a broad range of stroke severity, we doubled the number of stroke survivors to 20 and continued recruitment until 20 stroke survivors were successfully tested. Ten controls were recruited matching (1) the ratio of men and women and (2) the age profile of the recruited stroke survivors.

Baseline Assessments

We recorded each participant's age, and measured height and weight. For stroke survivors, we recorded date of stroke, severity of stroke, and stroke subtype. Stroke severity was assessed using the National Institutes of Health Stroke Scale (NIHSS),[14] which consists of 11 items. Severity was classified as mild (NIHSS <8), moderate (NIHSS 8-16), or severe (NIHSS >6).[15] We classified stroke subtype using the Oxfordshire Community Stroke Project classification[16] into total anterior circulation infarct, partial anterior circulation infarct, posterior circulation infarct, lacunar infarct, and intracerebral hemorrhage.

We assessed fatigue in stroke survivors and healthy controls using the Fatigue Assessment Scale[17] before the start of the test protocol. It is a valid and reliable measure of fatigue in stroke[18] and nonstroke[17] populations and consists of 10 statements scored on a 5-point Likert-scale; a higher score indicates greater fatigue.[19]

Energy Demands

Energy demands were determined by measuring oxygen-uptake continuously over the total duration of the test protocol, using a portable metabolic cart (Oxycon Mobile Device, CareFusion, Sydney, Australia Pty Ltd). The